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Tetravalent Chromium (Cr^{4+}) as Laser-Active Ion for Tunable Solid-State Lasers

A. Seas, V. Petričević, and R. R. Alfano

SEMI-ANNUAL PROGRESS REPORT

PRINCIPAL INVESTIGATOR: Prof. Robert R. Alfano

Period Covered: 10/31/92 - 3/31/93

Institute for Ultrafast Spectroscopy and Lasers
Physics Department, Room J-419
City College of New York
138 Street & Convent Avenue
New York, N.Y. 10031

N94-119394
TETRAVALENT
CHROMIUM (Cr^{4+}) AS LASER-ACTIVE
ION FOR TUNABLE SOLID-STATE LASERS
Semiannual Progress Report, 31 Oct.
1992 - 31 Mar. 1993 (City Col1. of
the City Univ. of New York) 7 p
63/36 0187808

GRANT NUMBER: NAG-1-1346

ACCOMPLISHMENTS

During 10/31/92 - 3/31/93 the following summarizes our major accomplishments made under the NASA grant: NAG-1-1346

Self-mode-locked operation of the Cr:forsterite laser was achieved. Synchronous pumping was used to mode lock the forsterite laser resulting in picosecond pulses, which in turn provided the starting mechanism for self-mode-locking. The pulses generated had a FWHM of 105 fs and were tunable between 1230 - 1270 nm.

ABSTRACTS AND PRESENTATIONS

Several papers were published and presented during the covered period:

1. A. Seas, V. Petričević, and R. R. Alfano, "Generation of Ultrashort Pulses From Cr⁴⁺:Forsterite", presented at the IEEE/LEOS 1992 Annual Meeting, Boston, Massachusetts, November 16-19, 1992.
2. V. Petričević, A. Seas, and R. R. Alfano, "Current Advances in the Development of Femtosecond Forsterite Lasers", presented at the SPIE's International Simposia on Optoelectronic Packaging and Interconnects, Laser Engineering, and Biomedical Optics, Los Angeles, California, 16-23 January 1993.
3. A. Seas, V. Petričević, and R. R. Alfano, "Femtosecond Pulses Generated From a Synchronously Pumped Chromium-Doped Forsterite Laser", presented at the Topical Meeting on Advanced Solid-State Lasers, New Orleans, Louisiana, February 1-3, 1992.
4. V. Petričević, A. Seas, and R. R. Alfano, "Current advances in the development of femtosecond forsterite lasers", to be published in the Proceedings of SPIE's International Simposia on Optoelectronic Packaging and Interconnects, Laser Engineering, and Biomedical Optics, Los Angeles, California, January 16-23, 1993
5. A. Seas, V. Petričević, and R. R. Alfano, "Femtosecond Pulses Generated From a Synchronously Pumped Chromium-Doped Forsterite Laser", To be published in the

Proceedings at the Topical Meeting on Advanced Solid-State Lasers, New Orleans, Louisiana, February 1-3, 1992.

6. V. Petričević, A. Seas, and R. R. Alfano, "Cr:Mg₂GeO₄ and Cr:CaMgSiO₄: New Potential Tunable Solid-State Laser Crystals", To be published in the Proceedings at the Topical Meeting on Advanced Solid-State Lasers, New Orleans, Louisiana, February 1-3, 1992.

RESEARCH PROGRAM

SELF-MODE-LOCKED Cr:FORSTERITE LASER

The observed mechanism of generation of femtosecond pulses from the active-mode locked forsterite laser suggests that femtosecond pulses can be generated from chromium doped forsterite laser without the need of active modulation.¹ In order to achieve pure self mode locked operation we design the laser shown in figure 1. The cavity is the same four mirror astigmatically compensated cavity used before but now pumping is provided by a CW mode-locked Nd:YAG laser. We removed the acousto-optic modulator and the birefringent plate, and we inserted an aperture between the second prism and the end mirror M_4 for tuning purposes.

The main idea behind this experiment is that picosecond pulses will be generated by adjusting the length of the forsterite laser to match the frequency of the pumping CW mode-locked Nd:YAG laser (synchronously-pumped mode-locking). These picosecond pulses in turn will generate the passive modulation and provide the starting mechanism for self mode-locking.

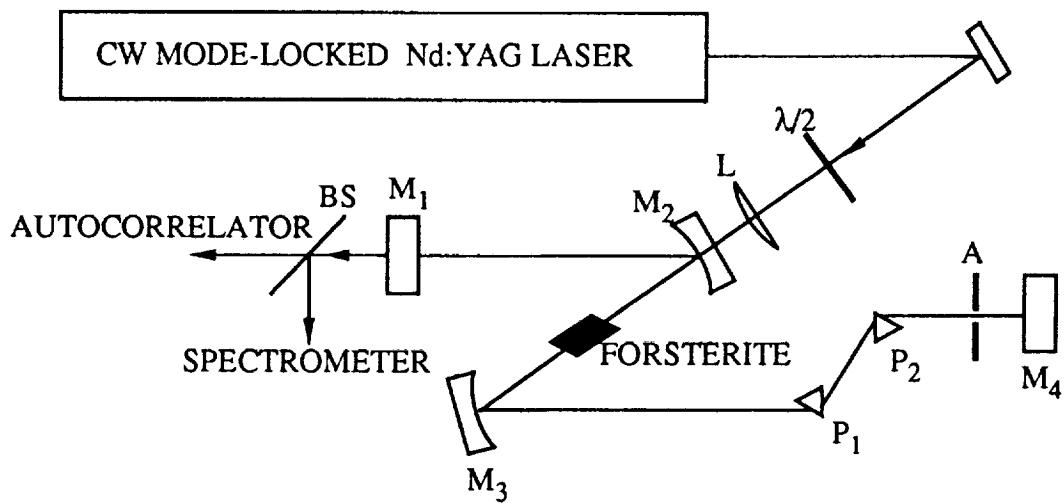


Fig. 1. Synchronously pumped forsterite laser design engineered for the generation of femtosecond pulses and self-mode-locking.

Synchronously pumped mode locking was observed when the length of the forsterite laser cavity was matched to the length of the Nd:YAG laser. The output pulses of the synchronously pumped forsterite laser had duration of the order of 200-300 ps. By careful optimization of the cavity by adjusting the position of the laser crystal with respect to the two folding mirrors, the forsterite laser was self mode-locked and the pulsedwidth was reduced to 105 fs with a spectral width of the order of 15 nm. In order to confirm that self mode-locking was achieved the cavity length was increased while monitoring the pulsedwidth and the pulse train on the oscilloscope. The forsterite laser continued to generate femtosecond pulses even when the length of the cavity was changed by few centimeters. This clearly indicated that the forsterite laser was self mode-locked and that synchronously pumped mode-locking acted as the starting mechanism for self mode-locking. The output power of the forsterite laser when femtosecond pulses were generated was 60 mW.

An intensity autocorrelation trace and the corresponding spectrum of a typical pulse are shown in figure 2 (a) and (b). The pulsedwidth shown is 105 fs and the bandwidth is 16 nm. The pulsedwidth-bandwidth product $\Delta\tau_p\Delta\nu = 0.32$, indicating transform-limited pulses assuming sech^2 pulses.

Figure 3 shows an oscilloscope photograph of the interferometric autocorrelation trace of the output pulses. Since there is good visibility of the fringes at the wings of the pulse it is evident that the pair of prisms compensated for the chirp introduced by the forsterite crystal. The self mode-locked forsterite laser was tuned using an aperture mounted on a translation stage between prism P_2 and mirror M_4 . Continuous tuning of the laser was achieved between 1240 and 1270 nm limited only by the dielectric coating of the mirrors. The duration of pulses did not vary throughout the whole tuning range.

The stability of the self mode-locked forsterite laser was greatly improved as compared with the previous experiments where the acousto-optic modulator was part of the cavity. The forsterite laser was operating in a self mode-locked mode for up to one hour without significant change in the output pulse characteristics. We believe that the improvement was mainly due to the

absence of the losses and phase distortions due to the mode locker and the birefringent filter.

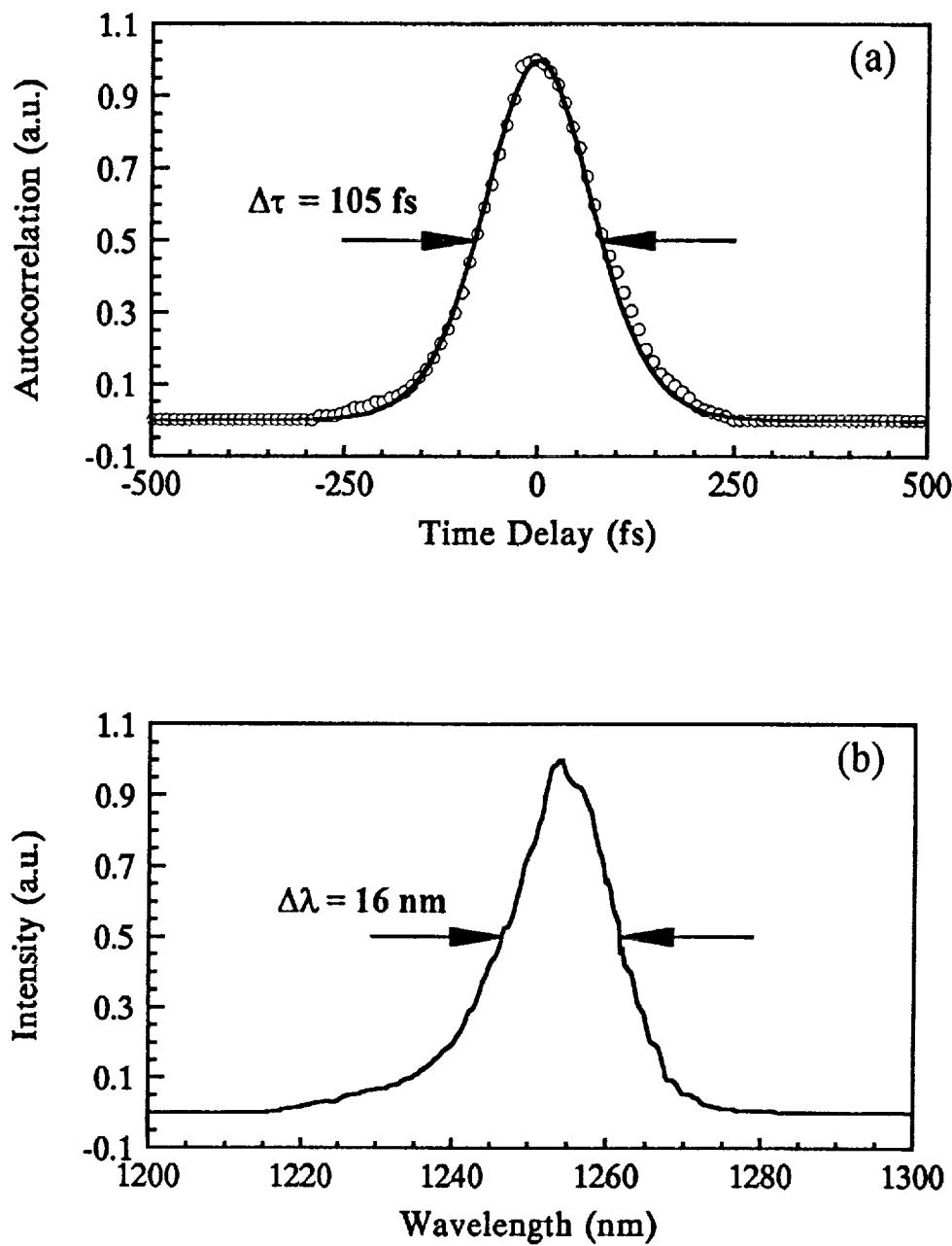


Fig. 2. An autocorrelation trace (a) and spectrum (b) of 105-fs pulses obtained from a z-fold cavity with SF 14 prisms for chirp compensation. Circles represent experimental data and the solid line is the best fit for sech^2 pulse shape.

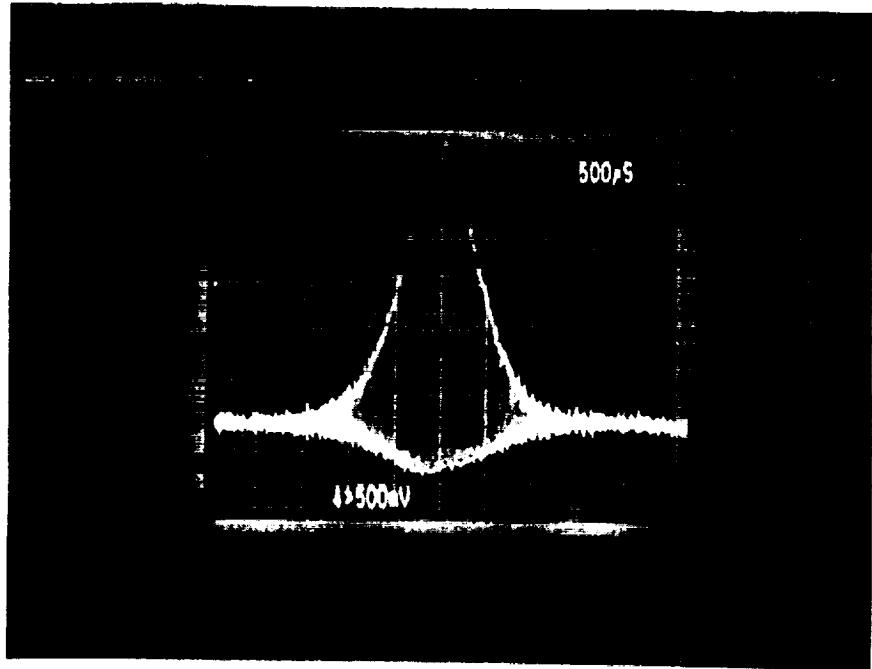


Fig. 3. Interferometric autocorrelation of the output pulses of the forsterite laser.

REFERENCES

1. A. Seas, V. Petričević, and R. R. Alfano, "Generation of Sub-100-fs Pulses From a Continuous-Wave Mode-Locked Chromium-Doped Forsterite Laser", *Optics Letters*, Vol. 17, pp. 937 (1992).